Simulation of Minimization of Wake Effects Using Steering

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Outline

- Simulation of transverse wakes
- Simulation of linac in **elegant**
- Loading structure displacement data
- Optimization of steering to reduce wake effects
- Discussion

Simulation of Transverse Wakes

- The transverse wake relates the displacement of a drive particle *d* to the kick received by a witness particle *i*

$$\Delta y_i' = \frac{e}{m_e c^2 \gamma} q_d y_d W_y(t_i - t_d)$$

- For a beam with many particles, this becomes

$$\Delta y'(t) = \frac{e}{m_e c^2 \gamma} \int_{-\infty}^{t} d\tau I(\tau) \langle y(\tau) \rangle W_y(t - \tau)$$

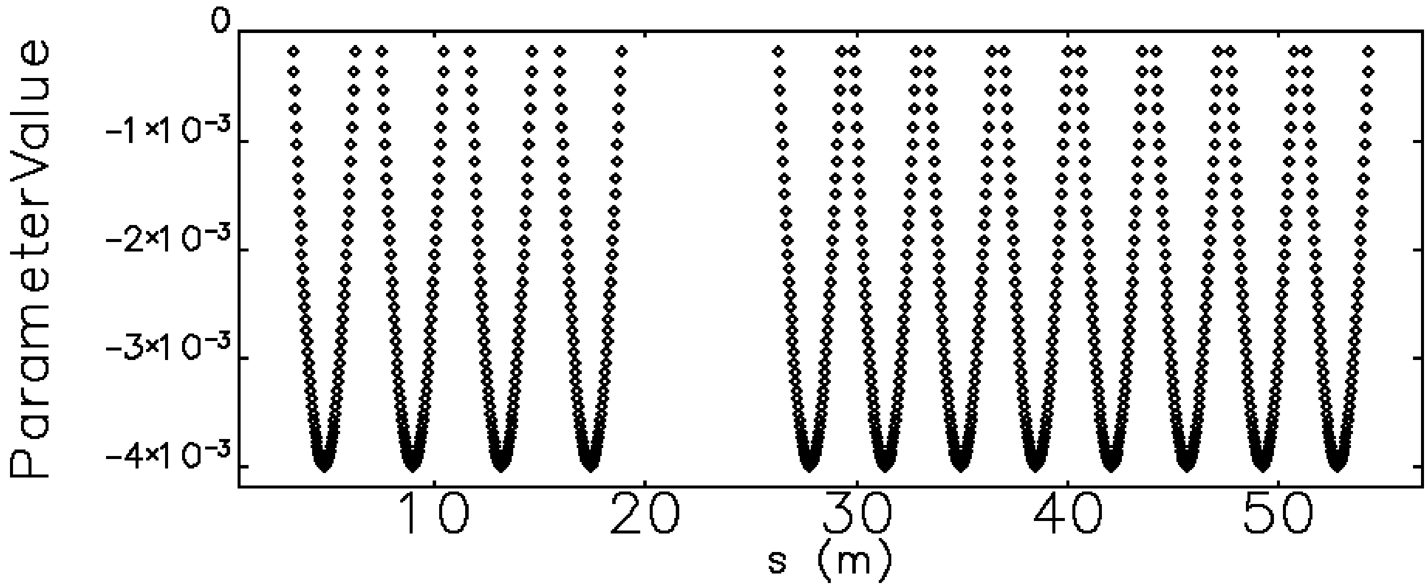
- In **elegant**
  - Wake function $W_y(t)$ is supplied as an SDDS file giving values from 0 to some maximum
  - Values are equispaced with interval Δt
  - Particle distribution is binned with interval Δt
  - Charge-weighted first moment is computed for each bin
  - Convolution with the wake function gives the kick vs t
  - Interpolation gives the kick for each particle

Simulation of Linac in elegant

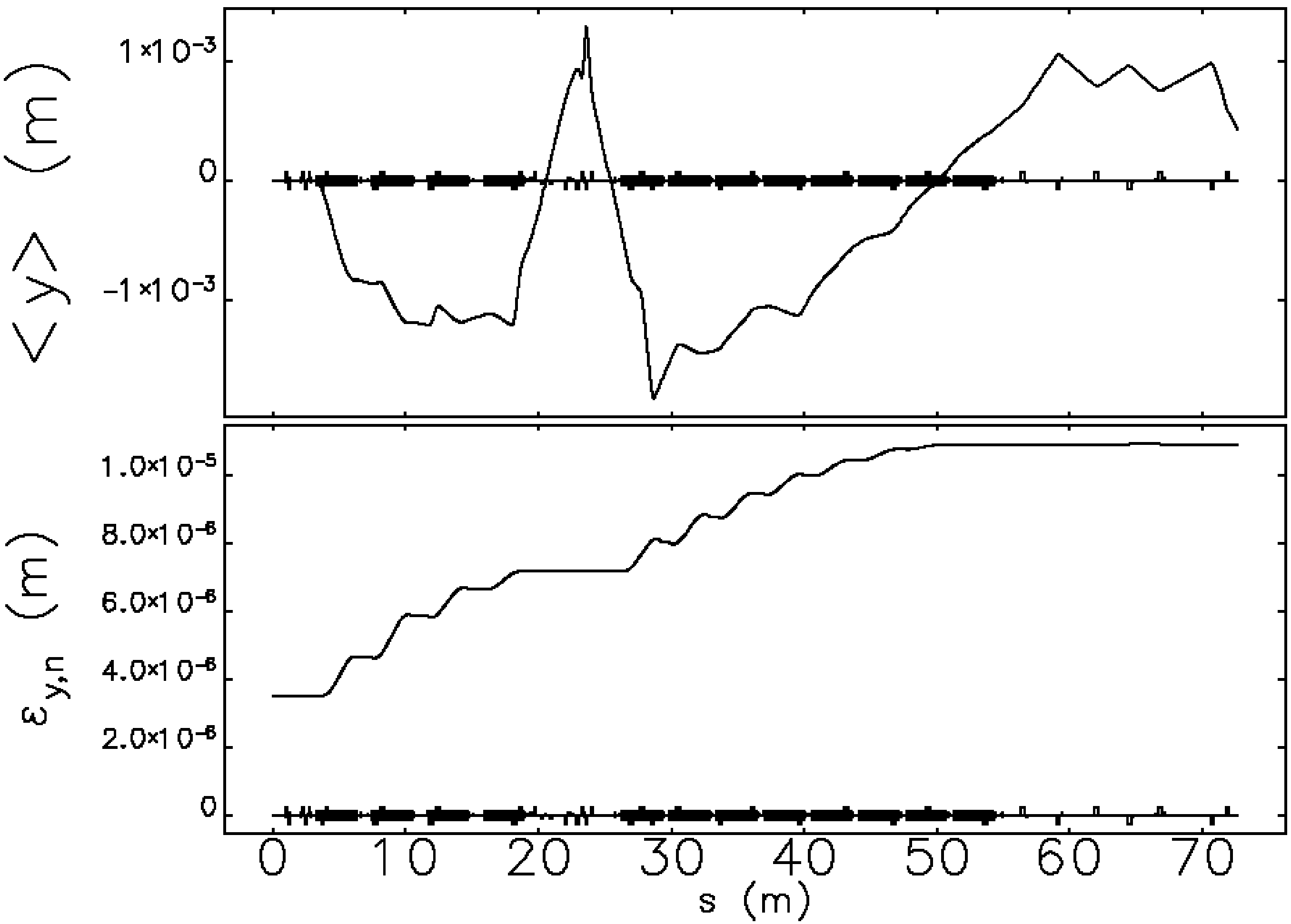
- The APS linac has quadrupoles over the rf structures
  - Structures are ~3m long
  - Quads have ~13.6 cm (15Q15) or ~28.7 cm (15Q30) effective lengths
- Since **elegant** is a lumped-element code, this presents a problem
- Must break the rf structures into pieces with thin-lens quadrupoles between
  - Linac cells are 3.5 cm long
  - 15Q15: five thin-lens quads with one-cell separation
  - 15Q30: nine thin-lens quads with one-cell separation
- Each linac cell is modeled with an RFCW element that includes
  - Acceleration (first-order matrix with exact phase dependence)
  - End focusing (kicks)
  - Wakes (kicks at exit)

Loading Structure Displacements

- RFCW has displacement parameters DX and DY
- Each 3m structure has 86 cells
- To avoid having to define each one by hand, we can use the &load_parameters command in **elegant**
  - Accepts an SDDS file with numerical values for properties of beamline elements
- As an example, applied a quadratic distortion of each structure with -4mm displacement at the center and 0mm displacement at the ends



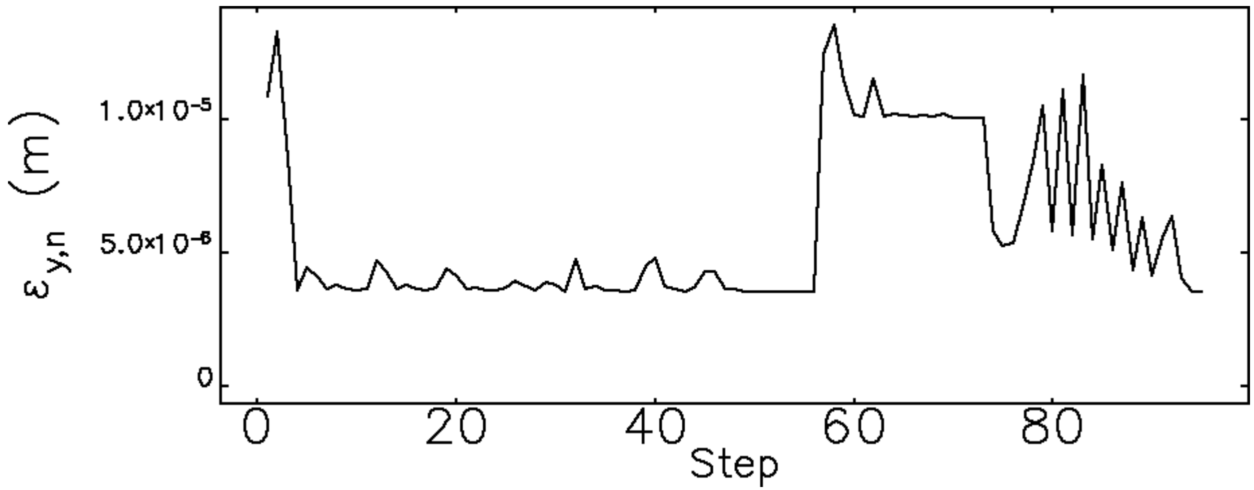
Effect of Hypothetical 4mm Sag



Simulation uses beam from PARMELA model of the injector (J. Lewellen).

Correction of Emittance

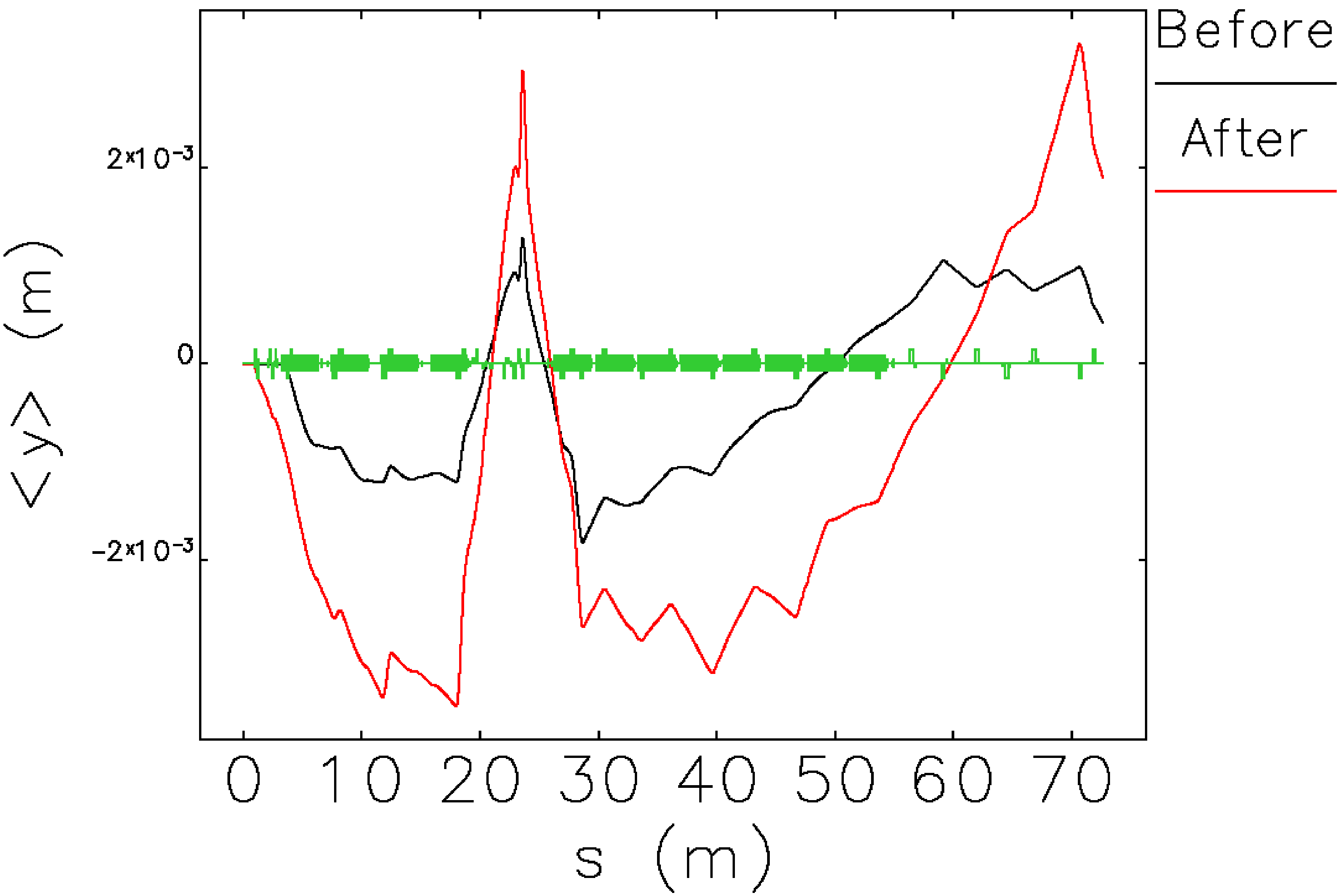
- Used steering to correct the emittance back to the initial value[1,2]
- Used **Pelegant**'s simplex optimizer to
  - Minimize the final vertical emittance
  - Ensure that no particles were lost
- 15 variables used
  - Two correctors upstream of L2
  - Correctors after each linac structure (12 total)
  - Corrector in bunch compressor region



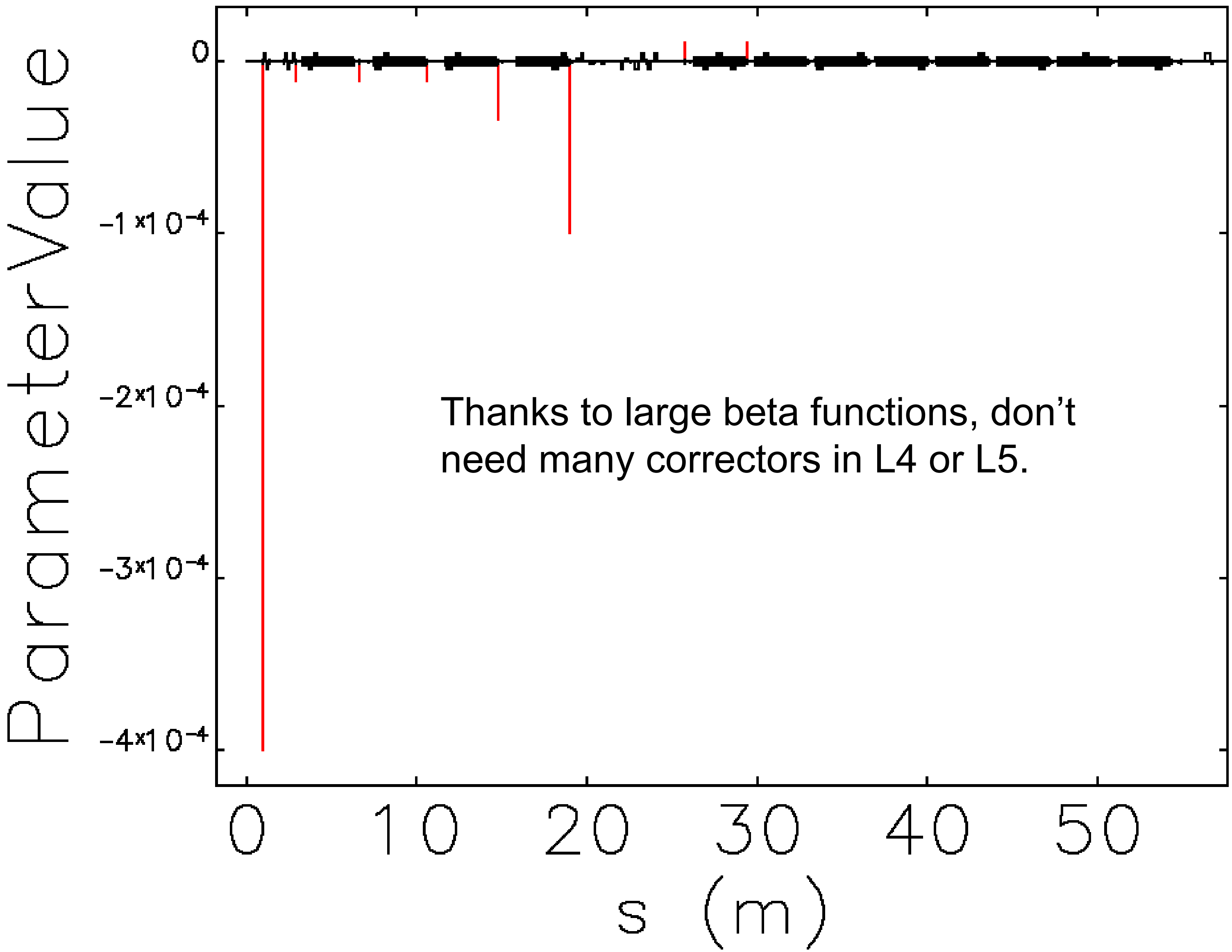
Optimization with Pelegant converges quickly

1: J. T. Seeman et al., SLAC-PUB-5705 (1992).
2: E. Lessner, Linac 2000, 851 (2000).

Details of Corrected Solution (Centroid)

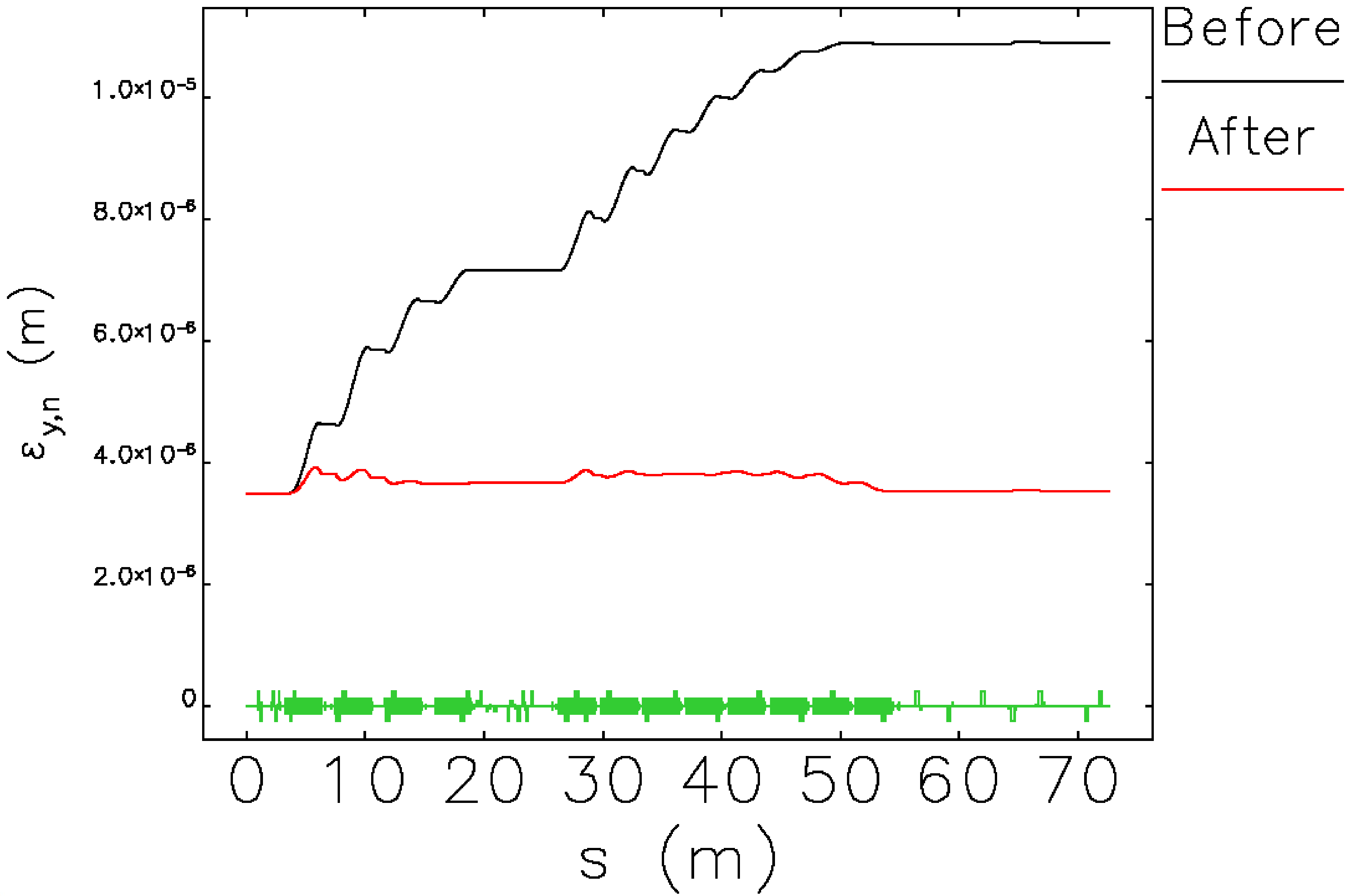


Details of Corrected Solution (Kicks)

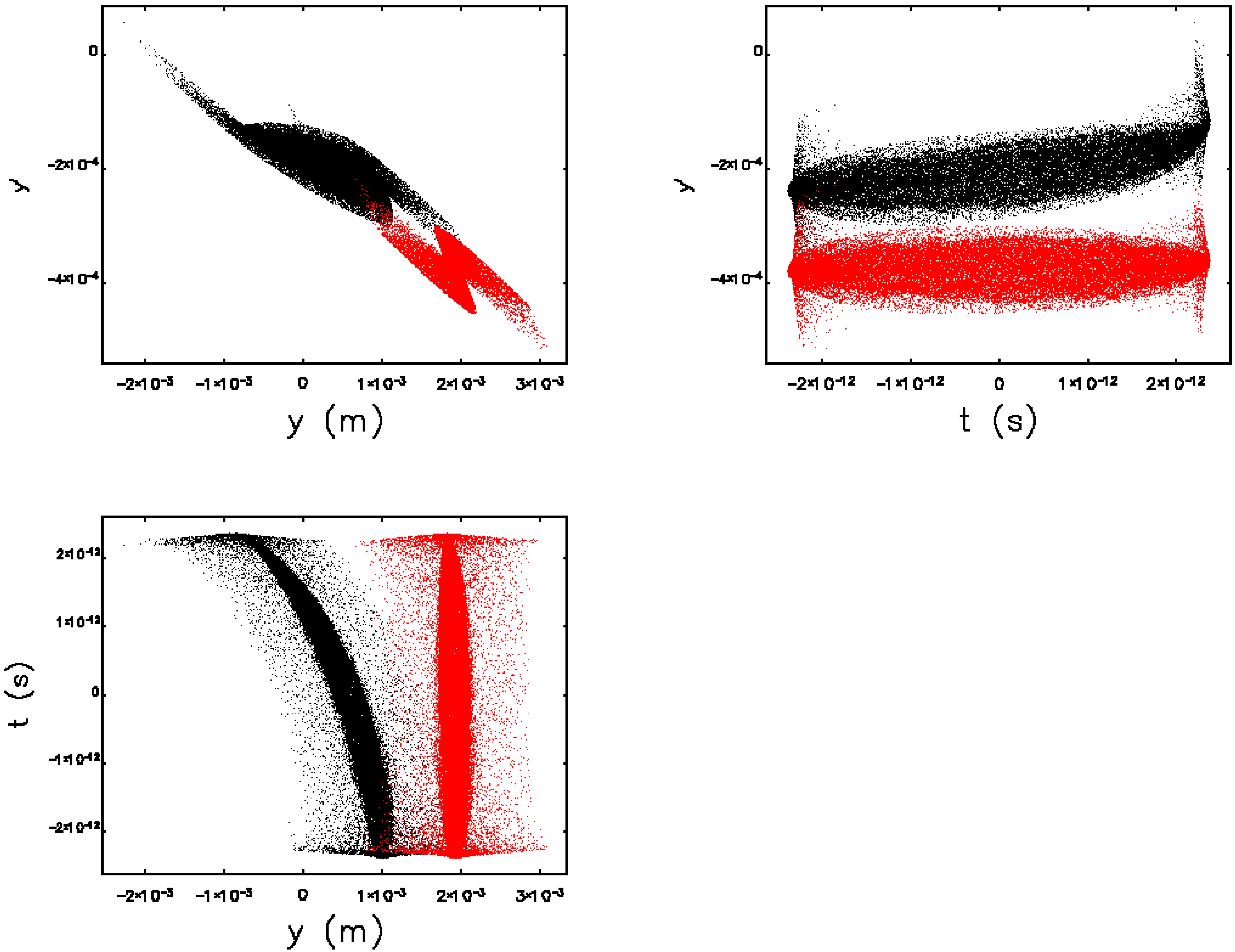


Thanks to large beta functions, don't need many correctors in L4 or L5.

Details of Corrected Solution (Emittance)



Details of Corrected Solution (Phase Space)



Discussion

- Using steering to cancel the effect of wakefields works very well in simulation
- In reality, may be problematical
  - If wakes are strong, three-screen emittance measurement will be unreliable
  - If beam isn't already matched, three-screen system isn't reliable
  - Emittance measurement is noisy in any case, which hampers optimization
- Could explore other optimization goals, e.g.,
  - Minimize average size of beam at the three screens
  - Minimize sensitivity of trajectory to change in bunch charge
- These could be tested in simulation